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Vegetation Report

Pumice Vegetation Management Project

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Vegetation Report

Introduction

The lack of natural fire during the last century has caused an increase in tree density and shifts in species composition in many forests in the western United States with a history of frequent fire (Knapp et al. 2013). This change has often resulted in a reduction in the amount of shade intolerant species such as ponderosa pine, while increasing the amount of shade tolerant species such as true firs (Taylor 2010). The unregulated and correspondingly high stocking levels of understory species provides ladder fuels necessary for stand replacing wildfire (Lydersen et al. 2013).

Studies have shown that spatial structure of fire-frequent forests is a mosaic of openings, widely spaced trees, and clumps. This diversity is typically found at small scales of less than half an acre. The quantity of each of these elements is variable but appears broadly characteristic of fire-frequent forests (Larson and Churchill 2012). This spatial pattern has greater resilience to both drought and stand-replacing wildfire. In addition, interspersed tree groups with high canopy cover and gaps, and a matrix of low-density trees provides necessary habitat for a range of wildlife species (Humble and Burnett 2010).

In the absence of frequent, low-intensity fires, stand density and tree competition increase, making many forests susceptible to insect attack. Drought further increases susceptibility to attack (Agwin 2013). Furthermore, increases in stand and landscape level heterogeneity may reduce bark beetle mortality while maintaining endemic (low) levels. In contrast, forested landscapes that contain little heterogeneity promote large contiguous areas susceptible to epidemic outbreaks (Agwin 2013).

For these reasons, it is necessary to manage stands with high stocking levels and homogeneous conditions, such as those in the Pumice project area. A variety of size and age classes, along with an increase of shade intolerant species such as ponderosa pine are key to improving resilience (Larson and Churchill 2012).

Methodology

Data for this project was collected using Common Stand Exam (CSE) protocol. Based on priority of treatment and available funding, some stands did not have exam data collected. Walk-throughs in all stands verified stand conditions and initiated treatment development. Exam data was downloaded into the Forest Service Vegetation program (FSVeg). This program summarized the stand condition data and assisted in the development of prescriptions.

The Forest Vegetation Simulator (FVS) is the primary model used to display stand conditions after treatments and future conditions. The FVS bases these projections on incorporation of growing conditions for regional variants and individual stand conditions. On the Klamath National Forest (Forest), the Southern Oregon Northeastern California variant was used. The modeled results show relative differences between treatments and are not intended to be used as absolutes. The FVS models treatments over the entire stand, spacing remaining trees evenly, making spatial diversity difficult to discern. With other variables being equal, indicators for treatment success show a relative comparison between alternatives.

GIS layers helped identify roads, past harvest activities, vegetation types (CALVEG), stand boundaries, and topographic information for analysis and the development of treatments.

Analysis Indicators

The following indicators were used to evaluate the effects of treatment on vegetation for each alternative, and show changes in stand density, species composition, and structural diversity:

- **Stand Density Index (SDI) measured immediately after treatment and 30 years post-treatment.** This will determine the effectiveness of treatment overtime. SDI will be expressed as a percentage of the maximum SDI value. This value will provide a method to assess general forest health by alternative. For example, 35 percent of SDI maximum is where site conditions are fully occupied, and 55 percent of SDI maximum is when competition induced mortality can be expected (Long and Shaw 2005). See Appendix C for a more detailed description of SDI.
- **Percentage of ponderosa pine measured immediately after treatment and 30 years post-treatment.** This indicator will illustrate how effective alternatives are at providing conditions suitable for shade intolerant species that have historically been present.
- **Acres of openings and no-treatment retention clumps displayed by alternative and conifer type.** The number of acres in created openings will illustrate the capability to develop a new age class. No-treatment retention clumps represent acres with the highest density. This will provide a way to quantify spatial changes in stand structure.
- **Diameter distribution curve measured immediately after treatment and 30 years post-treatment.** This will graphically show the number of trees in each diameter class over time. This will illustrate how effective each alternative is at creating size class diversity.

Spatial and Temporal Bounding of Analysis Area

Landscape level conditions may impact vegetation; however, significant changes to vegetation are most likely to happen in the immediate surroundings of the treated vegetation. Spatial boundaries, for direct and indirect effects, will be limited to the stands treated. Spatial boundaries for cumulative effects will be limited to the project area.

Temporal bounding measures the effects immediately following treatment and extends 30 years post treatment. This is an adequate time frame in which to model differences between alternatives.

Affected Environment

The Pumice Project is located in the mid- to upper-montane ecological zone of the Southern Cascades bioregion (Skinner and Taylor 2006). The project area includes 9,056 acres and proposes to treat up to 6,240 acres. There are 247 acres of private land within the project area, which are excluded from treatment. Elevation ranges from 5,500 to 7,000 feet. Topography is rolling with slopes generally below 20 percent. Overall, most of the stands are characterized as mid-seral in development with high stocking levels.

Influences on Existing Condition

Past logging activities and fire exclusion have influenced current stand conditions. Railroad logging in the first half of the last century selectively removed large ponderosa pines. Based on GIS layers, Forest Activities Tracking Center database and stand record cards, logging activities began in the 1980s and early 1990s. Types of harvest included clearcutting, shelterwood, overstory removal, seed tree, commercial thinning and single tree selection. These activities contributed to the reduction of shade intolerant species such as ponderosa pine and prolific regeneration of white fir, most of which is currently approximately 80 years old.

Historically, low-intensity wildfire maintained the presence of shade intolerant species and provided spatial diversity which improved resilience to high intensity wildfire and forest health issues (Taylor and Skinner 2003). Based on the biophysical setting GIS layer developed by U.S. Geological Survey for red fir and white fir, historic fire frequency within the project area is approximately 35 years. The Forest fire atlas indicates that 3 fires have occurred since 1917, totaling 2,355 acres within the 9,310-acre project area.

Existing Conditions

The CALVEG GIS layers identified four conifer plant series in the project area. Plant association or a subset of taxonomically related communities further distinguished each series. This report will address the following conifer series: lodgepole, mixed conifer, white fir and Shasta red fir. Table 1 displays the size class distribution within the project area and the dominant conifer series associated with each size class.

Table 1. Tree size class distribution in the project area

Size Class (inches)	Acres	Percentage of Project Area	Dominant Conifer Series
≥ 24	176	2%	Shasta red Fir
11 to 23	5,970	66%	mixed conifer, white fir
6 to 11	2,532	28%	lodgepole
1 to 6	378	4%	Shasta red Fir

This table highlights the lack of mature forest structure and the abundance of mid-seral conditions. The majority of the 6 to 11-inch size class is within the lodgepole series. Past regeneration harvests in the red fir series comprise most of the 1 to 6-inch class, which are now young regenerating stands.

To refine conifer series at the stand level, stand exams were used to make a determination based on species composition. The transition zones between series were broad as topography is rolling with a gradual rise in elevation. The analysis of effects is based on how each series is affected by alternatives. The following is a description of the affected environment by series.

Mixed Conifer Series

Elevations range from 5,500 to 5,800 feet and annual precipitation ranges from 20 to 30 inches. The stands are generally even aged and mid-seral in development. There are a few natural and harvest created openings, but in general, they lack structural diversity. Ponderosa pine occupies 13 percent of the overstory with very little natural pine regeneration. Stand composition includes 57 percent white fir, 30 percent lodgepole, and 13 percent ponderosa pine. Based on stand exam data the average stocking level of the understory is 852 trees per acre (0.3 to 10.9 inches

diameter at breast height [DBH]), while the overstory contains an average of 105 trees per acre (greater than or equal to 11 inches DBH). Size class of the overstory generally ranges from 11 to 23 inches DBH with a minor component exceeding this range. This series has an SDI value of 511, putting it at 79 percent of the SDI maximum of 650. This level reflects intense inter-tree competition. Under these conditions, trees are competing for more resources than are available. Stand walk-throughs noting diminished growth rates, low crown ratios, and poor needle compliment verify this competition.

Photo 1

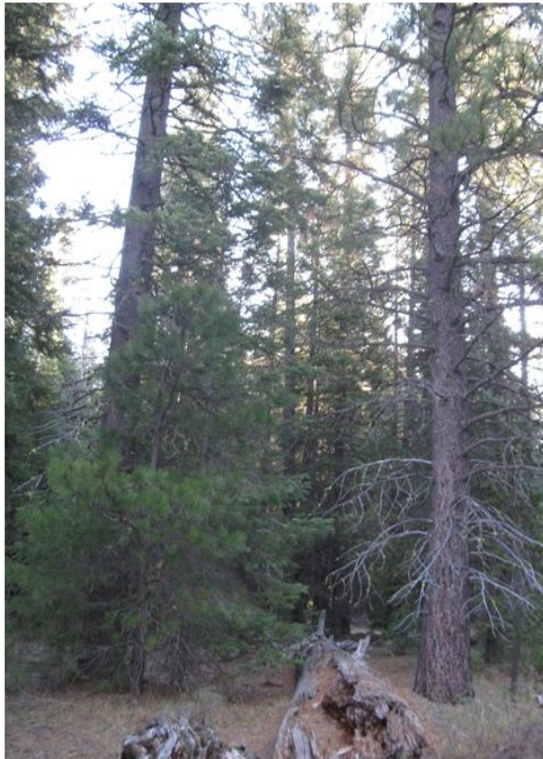


Photo 2



Figure 1. These photos illustrate encroaching shade tolerant species in the mixed conifer stands leading to inter-tree competition and low resilience to disturbance factors.

Currently, within the mixed conifer series there are endemic levels of insects, with pockets of high mortality noted in stands 745-90 and 745-38. These stands are located adjacent to lodgepole stands which have had epidemic levels of mountain and western pine beetle (see Appendix A - Pathogens).

Fir engraver (*Scolytus ventralis*) is a host-specific beetle to true firs. This beetle will usually attack the tops of trees as vigor declines due to competitive stresses. White fir within this series are showing signs of stress with fading tops. The beetle is common throughout this series and at the upper end of being at endemic levels.

Root disease (*Armillaria mellea* and *Heterobasidion annosum*), mainly noted in the white fir, is endemic and found in patches through this series. High stocking levels and past logging damage provide opportunities for this fungus (Wood et al. 2002; Agwin 2013).

White Fir Series

Elevations range from 5,800 to 6,500 feet and annual precipitation ranges from 30 to 40 inches. Stands within this series are mid-seral and even aged with closed canopy conditions. As in the mixed conifer series, these stands lack structural diversity with high levels of inter-tree competition. Species composition averages 60 percent white fir, 20 percent lodgepole, 14 percent Shasta red fir, and 6 percent ponderosa pine and sugar pine. Based on a representative sample of stand exam data the average stocking level of the understory is 689 trees per acre (0.3 to 10.9 inches DBH), while the overstory contains an average of 118 trees per acre (greater than or equal to 11 inches DBH). Size class of the overstory generally ranges from 11 to 23 inches DBH with a minor component exceeding this range. Most of the larger trees are found in the parent stand 744-59. Ponderosa pine occupies 6 percent of the overstory with virtually no natural regeneration. Current SDI levels are 537, putting this series at 72 percent of the SDI maximum of 750.

Insects and disease are endemic, with root disease and fir engraver beetle attacking intermediate to codominant white fir. Larger trees are succumbing to competitive stresses as evidenced by slowing vertical growth and fading and dead tops. These larger trees are no longer able to maintain moisture requirements and are succumbing to competitive stresses as evidenced by poor vigor and fading tops. Stand exam data indicates that there are approximately 3.1 snags per acre, averaging 20 inches DBH. Stand 59 is unique in that it has approximately 5.25 snags per acre, averaging 21 inches DBH.

Photo 3



Photo 4



Figure 2. Photo 3 is representative of white fir stands with high stocking levels. These stands have basal areas ranging from 250 to 500 square feet per acre. Lower limbs have been self-pruned due to competition and crown ratios are between 20 to 40 percent. Photo 4 illustrates homogeneous condition leading to decreasing representation of shade intolerant conifers. In the center of the picture is a ponderosa pine with fading crown overshadowed by shade tolerant white fir.

Photo 5



Photo 6



Figure

Figure 3. Photo 5 shows a stand with no past thinning. Shade tolerant species have occupied the understory, increasing competition and reducing growth of overstory trees. Photo 6 shows a thinned stand, where overstory trees have been allowed to develop and fully occupy the canopy. Under these conditions, even shade tolerant species have difficulty regenerating.

Red Fir Series

Elevations range from 6,500 to 7,000 feet with annual precipitation over 40 inches. This series is capable of maintaining stand health with high stocking levels (Laacke 1990). There is more structural diversity in the red fir series than found in mixed conifer or white fir. Railroad logging in the first part of the last century did not affect this portion of the district. Therefore, most size classes over 24 inches DBH are located in this zone. There is a relatively well-balanced mix of size classes.

Few stands within this series were sampled with stand exams, therefore, stand conditions are based on walk-through information. Species composition averages 60 percent Shasta red fir, 20 percent white fir, 19 percent lodgepole and one percent or less of ponderosa pine and sugar pine. Stocking level of the understory averages 1,250 trees per acre (0.3 to 10.9 inches DBH), while the overstory contains an average of 202 trees per acre (greater than or equal to 11 inches DBH). Size class of the overstory varies, with a substantial increase in the number of trees over 23 inches DBH. The current SDI for this series is 540, equating to 60 percent of the SDI maximum of 900. At this level, competition induced mortality would be expected. Field reviews noted very few insects and disease. The exception was mature stands showing signs of root disease.

Photo 7



Photo 8



Figure 4. Photo 7 illustrates a mature red fir stand with a size class 24 inches or greater. Photo 8 is an example of a clear-cut implemented in the 1980s, which has developed into a stand with sapling and pole sized conifers and a healthy shrub component.

Photo 9



Photo 10



Figure 5. Photos 9 and 10 show mid-seral development of a red fir stand with high stocking levels.

Lodgepole Pine Series

Elevations range from 5,600 to 5,800 feet and annual precipitation ranges from 30 to 40 inches. This series is delineated by the presence of cold air drainage that settles in the low flat terrain

found within this project. For this reason, productivity is low and commercial opportunities are limited. Stand exams were not taken in this series, therefore, the following information is based on stand walk-throughs. Strip clearcutting in productive stands was harvested in the 1980s and 1990s. Remaining trees range from mature to over mature with stocking levels of 250 to 350 trees per acre. Size class of the overstory is 10 to 14 inches DBH. Trees have low crown ratios, poor vigor, and are actively being attacked by bark beetle. Regeneration in the strip clear cuts have stocking levels of 1,200 or more trees per acre. The size class of these trees are 0.3 to 6 inches DBH. Species composition is close to 100 percent lodgepole. Current SDI levels are estimated at 382. Using 580 as SDI maximum, this equates to 66 percent of SDI maximum.

Insects are prevalent in this series and are approaching epidemic levels as evidenced by high mortality rates.

Photo 11



Photo 12



Figure 6. Photo 11 shows a strip clear cut completed in the 1980s through the 1990s. It has since regenerated with sapling sized lodgepole. These strips will have the small tree diameter trees thinned with this project. Photo 12 shows a leave strip that has become mature to over mature, with high mortality rates.

Environmental Consequences

This section will analyze the effects that each alternative has on the conifer series discussed in the affected environment.

Alternative 1 – No Action

Direct and Indirect Effects

Although the no action alternative would not have direct effects, it would have indirect consequences. Without treatment, SDI levels would continue to rise. As competition increases, insects and disease would continue to cause mortality, eventually reaching epidemic levels.

Ponderosa pine would continue to decrease as shade tolerant species occupy the site. Stand diversity would not be improved over the 30-year period analyzed in this report. There would be a lack of diversity of diameter class.

The following table shows results using FVS for each conifer series under Alternative 1. Ponderosa pine would decrease over time in the mixed conifer and white fir series. Ponderosa pine was not noted in either the lodgepole or Shasta red fir series. Existing SDI levels are all 60 percent or greater, indicating high levels of inter-tree competition (Long 1985; Reineke 1933). In 30 years, SDI levels would exceed 70 percent for all the conifer series, which is not sustainable.

Table 2. Alternative 1 FVS results

Conifer Series	Percent of existing ponderosa pine	Percent of ponderosa pine in 30 years	Current SDI	SDI in 30 years	Maximum SDI
Mixed conifer	13%	9%	79%	90%	650
Lodgepole*	0%	0%	66%	77%	580
White fir	6%	4%	70%	81%	760
Shasta red fir	0%	0%	60%	72%	900

*Data based on field observations (exams were not taken)

Cumulative Effects

Firewood gathering is the only ongoing action that could have an effect on regenerating stands, as it overlaps with project activities. Firewood gathering is limited to select lodgepole stands designated for firewood cutting, or dead and down vegetation along existing roads. As a result, impacts are limited to defined stands rather than widespread throughout the project area. Firewood gathering is not likely to have a measurable effect on the vegetation management analysis indicators for any alternative. Therefore, no cumulative effects are expected.

Alternative 2

A detailed description of this alternative can be found in the Pumice Environmental Assessment. Assumption for FVS modeling are found in Appendix D.

Direct and Indirect Effects

Table 3 below illustrates the effectiveness of treatment for each analysis indicator and conifer series for Alternative 2. Table 4 demonstrates how Alternative 2 encourages large tree development by shows existing conditions and 30 years after treatment by conifer series. Figure 7 through Figure 9 provide a graphic representation of Table 4.

Table 3. Alternative 2 Analysis Indicators

Conifer Series	No Treatment (Acres)*	Light thin	Heavy thin	Openings (Acres)	Percent ponderosa pine post treatment	Percent ponderosa pine after 30 years	SDI post treatment	SDI after 30 years	Acres Treated
Mixed conifer	330	100%	0	0	16%	22%	50%	73%	1,290
Lodgepole**	0	0%	100%	0	0%	0%	34%	56%	245
White fir	484	100%	0%	0	6%	6%	39%	71%	2,190
Red fir	86	100%	0%	0	0%	0%	34%	53%	564

*Reserve acres within treated stands.

**Data based on field observations (exams were not taken).

Table 4: Alternative 2 Diameter distribution by conifer series

Conifer series	8-inch diameter class	12-inch diameter class	16-inch diameter class	20-inch diameter class	24-inch diameter class	+28-inch diameter class
Mixed conifer immediately post treatment	17	49	33	17	8	3
Mixed conifer 30 years post treatment	12	34	37	22	13	8
White fir immediately post treatment	15	37	33	21	11	7
White fir 30 years post treatment	11	25	34	28	16	13
Shasta red fir immediately post treatment	23	78	47	13	5	2
Shasta red fir 30 years post treatment	17	27	52	38	18	7
Lodgepole immediately post treatment	4	5	0	0	0	0
Lodgepole 30 years post treatment	170	5	0	0	0	0

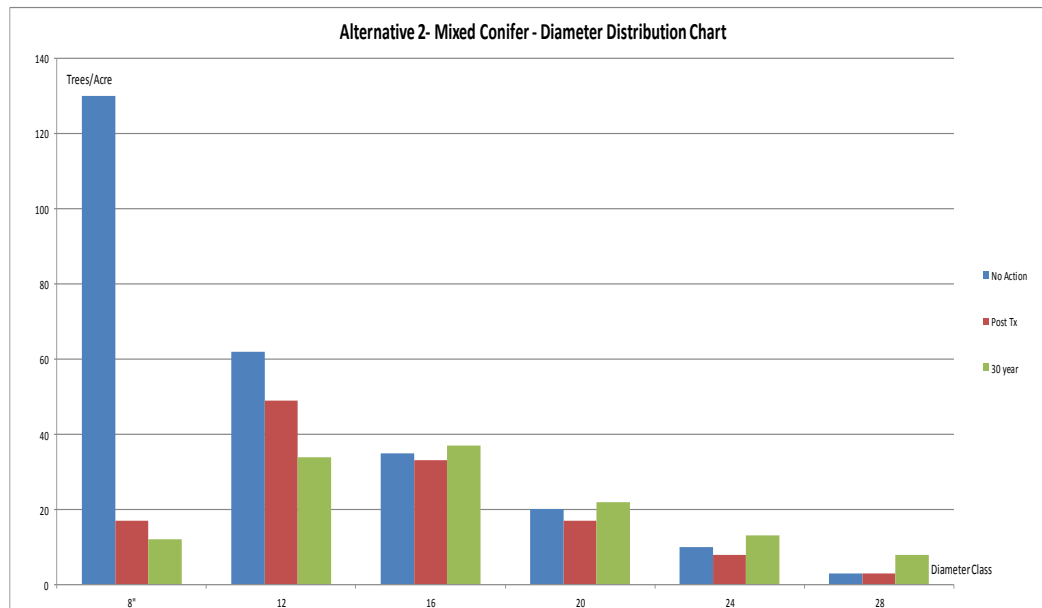


Figure 7: Alternative 2 mixed conifer diameter distribution

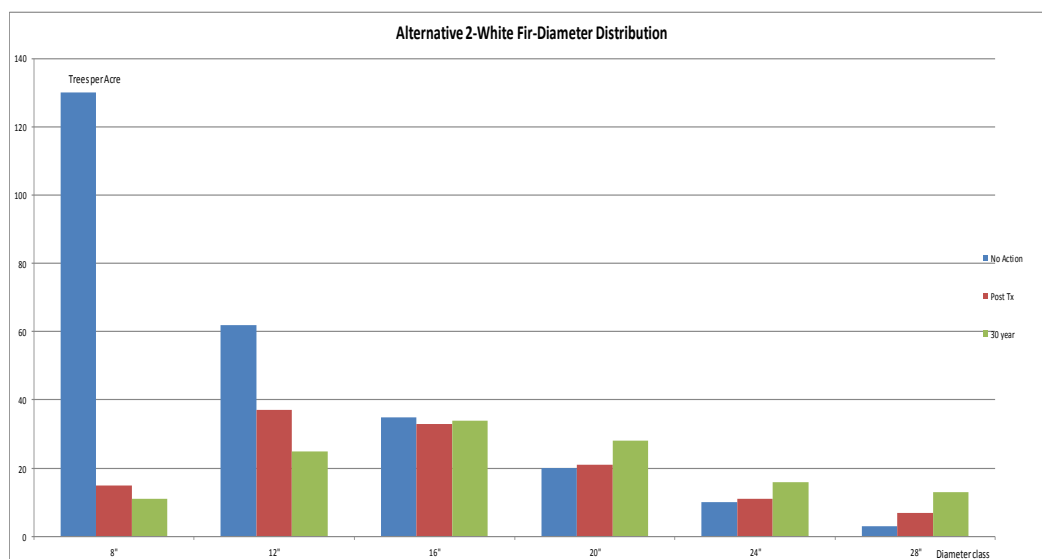


Figure 8: Alternative 2 white fir diameter distribution

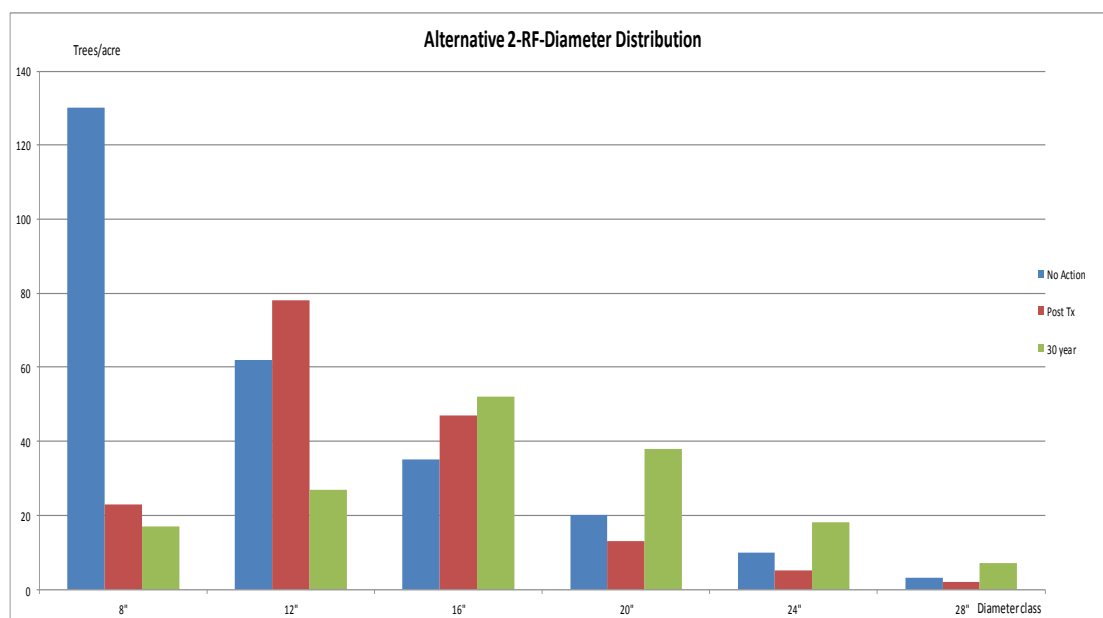


Figure 9: Alternative 2 Shasta red fir diameter distribution

Mixed Conifer Series

Retention of ponderosa pine as the preferred tree species, and the reduction of white fir would increase the relative percentage of ponderosa pine in stands. After 30 years, ponderosa pine would increase to 22 percent.

Due to lack of openings and the proposed light-intensity thinning, stand structure diversity would improve only slightly. Thinning would reduce SDI to 50 percent immediately post-treatment, providing minimal silvicultural benefit. This treatment would allow for some increased growing space allocation to remaining trees but would only allow for slight regeneration of less shade tolerant species. This would likely result in a loss of species diversity over time. Long term (30 years post-treatment), SDI would increase to 73 percent, however this is lower than the 90 percent SDI that would be expected long term if no action was taken. This stand would begin to see stress related mortality and reduced resilience to insect and disease unless another entry was made.

Diameters increase over the 30-year analysis period, but do not provide a range of size classes to increase diversity.

White Fir Series

Under Alternative 2, ponderosa pine would be unable to regenerate under the shaded conditions in this series. Ponderosa pine post treatment would maintain its presence at six percent over the 30-year period. Stand structure diversity would not be altered due to the lack of openings and light intensity thinning.

Treatment would lower SDI to healthy levels post treatment, increasing resiliency to biotic factors (insects and disease) as well as abiotic factors (wildfire and climate change) (Fitzgerald 2005). However, after 30 years, SDI would increase to 71 percent, dramatically increasing risk of disturbance factors as compared to immediately post treatment.

Diameters would increase over the 30-year analysis period but do not provide a range of size classes to increase diversity.

Red Fir Series

This alternative would lower SDI to productive levels post treatment. Thirty years after treatment, SDI would increase to 53 percent.

Currently only 13 percent of the red fir series is made up of ponderosa pine; Alternative 2 treatments would alter this only slightly. Due to lack of openings and a relatively small amount of retention clumps, stand structure diversity would not improve in treated stands.

Lodgepole Pine Series

The seed tree prescription and pre-commercial thinning would be effective in lowering estimated SDI to productive levels post-treatment. Over the 30-year period, estimated values would rise to 53 percent.

There is currently an absence of ponderosa pine in the lodgepole series; Alternative 2 treatments would not alter this. Treatments would maintain structural diversity as removal of mature to over-mature trees would initiate the growth of another age class.

Cumulative Effects

Same as Alternative 1.

Alternative 3

Direct and Indirect Effects

Table 5 below illustrates the effectiveness of treatment for each analysis indicator and conifer series for Alternative 3. Table 6 demonstrates how Alternative 3 encourages large tree development by showing existing conditions and 30 years after treatment by conifer series. Figure 10 and Figure 11 provide a graphic representation of Table 6.

Table 5. Alternative 3 analysis indicators

Conifer Series	No Treatment (Acres)*	Light thin	Heavy thin	Openings (Acres)	Percent ponderosa pine post treatment	Percent ponderosa pine after 30 years	SDI post treatment	SDI after 30 years	Acres Treated
Mixed conifer	393	0	100%	116	32%	53%	20%	39%	1,163
Lodgepole**	0	0%	100%	0	0%	0%	28%	56%	245
White fir	585	65%	35%	401	22%	16%	34%	52%	2,177
Shasta red Fir	86	100%	0	0	0%	0%	34%	53%	564

*Reserve acres within treated stands.

**Data based on field observations (exams were not taken).

Table 6. Alternative 3 diameter distribution

Conifer series	8-inch diameter class	12-inch diameter class	16-inch diameter class	20-inch diameter class	24-inch diameter class	+28-inch diameter class
Mixed conifer immediately post treatment	0	8	21	13	7	2
Mixed conifer 30 years post treatment	16	1	11	14	13	9
White fir immediately post treatment	5	15	18	16	9	5
White fir 30 years post treatment	1	6	10	15	15	16
Shasta red fir immediately post treatment	23	78	47	13	5	2
Shasta red fir 30 years post treatment	17	27	52	38	18	7
Lodgepole immediately post treatment	4	5	0	0	0	0
Lodgepole 30 years post treatment	170	5	0	0	0	0

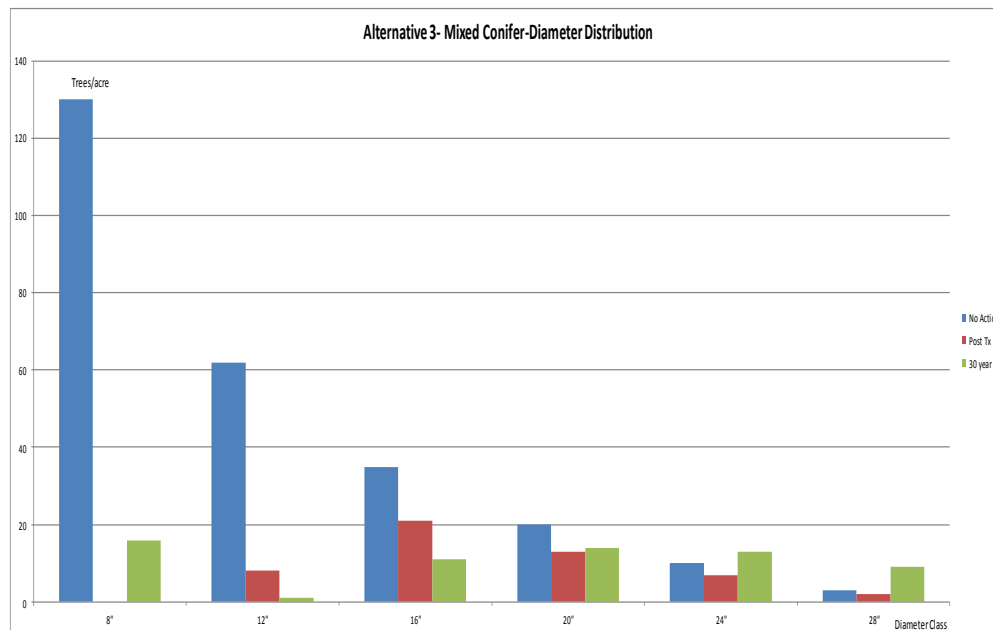


Figure 10. Alternative 3 mixed conifer diameter distribution

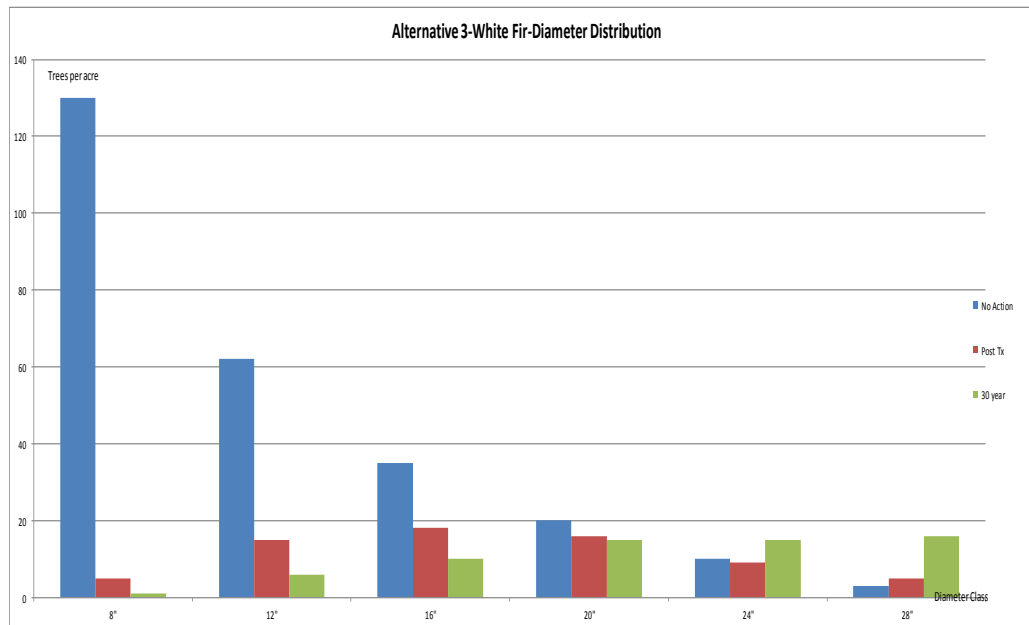


Figure 11. Alternative 3 white fir diameter distribution

Note: Red fir diameter distribution is not shown, as there is no difference between Alternatives 2 and 3.

Mixed Conifer Series

This alternative would reduce stocking levels and provide the best conditions suitable for natural pine regeneration of all alternatives. SDI levels would be dramatically lowered and improve resilience to disturbance over the 30-year analysis period. The effects of thinning would widen tree spacing, reduce inter-tree competition, and increase the amount of sunlight and water available for remaining trees. Crown foliage would be able to access more sunlight, increasing the rate of photosynthesis producing higher crown ratios over time. This would increase the photosynthetic surface area, providing additional energy for the tree to grow. Needle efficiency would improve as levels of chlorophyll rise in order to absorb energy from increased sunlight. With increased photosynthetic activity, tree diameter and height would increase (Bareja 2001).

This alternative would reduce stocking levels and provide conditions suitable for natural pine regeneration. Retaining ponderosa pine in the overstory and removing white fir would improve relative species composition of pine. Openings and heavy thinning would create conditions suitable for ponderosa pine regeneration, increasing the percentage of ponderosa pine.

Stand structure diversity would increase with openings, retention clumps and heavy thinning. Diameter distribution will shift to larger classes as thinning and prescribed fire remove most of the shade tolerant understory.

White Fir Series

This alternative would maintain healthy, productive stocking levels compared to the other alternatives. SDI would increase as trees occupy the site and begin competition. After 30 years, SDI levels should near 55 percent and the effects of inter-tree competition, including slower growth, poor needle compliment, and less resistance to disturbance factors, would be evident.

This alternative would maintain healthy, productive stocking levels, while providing openings and retention clumps. Planting ponderosa pine in openings would improve species composition. Edge effect in openings would slow growth of pine seedlings around the edge and provide white fir the opportunity to compete (York et al. 2003). Overtime, white fir would develop in the understory and reduce the relative percentage of pine. However, the planted pine would remain a viable component of the stand. Overall, this treatment would result in improved stand structure.

Diameter distribution is improved as trees develop into larger size classes.

Red Fir and Lodgepole Series

The effects to the Shasta red fir and lodgepole series are the same as in Alternative 2.

Cumulative Effects

Same as Alternative 1.

Comparison of Alternatives

The following table displays the effect each action alternative has on conifer series within the project area.

Table 1: Comparison of Analysis Indicators

Analysis Indicator	Mixed conifer Alt. 2	Mixed conifer Alt. 3	White fir Alt. 2	White fir Alt. 3	Shasta red fir Alt. 2	Shasta red fir Alt. 3	Lodgepole Alt. 2	Lodgepole Alt. 3
Acres in retention clumps	330	393*	484	585*	86	86	0	0
Light thin %	100	0	100	65	100	100	0	0
Heavy thin%	0	100	0	35	0	0	100	100
Acres in openings	0	233	0	435	0	0	0	0
% Ponderosa pine (post-treatment)	16	32	6	22	0	0	0	0
% Ponderosa pine (30 years)	22	53	6	16	0	0	0	0
SDI (post treatment)	50	20	39	34	34	34	28	28
SDI (30 years)	73	39	71	52	53	53	56	56
Total acres treated	1,290	923	2,190	2,199	564	564	245	245

*Retention clumps also include primary nest stands for northern goshawk

Summary of Effects

Mixed conifer series

Alternative 3 would be the most effective based on silvicultural analysis indicators. The percentage of ponderosa pine would be sustainable and would increase to 53 percent after 30 years. Creating openings, heavy thinning, and prescribed fire would provide an environment in which pine could regenerate.

SDI values would be at healthy and productive levels throughout the 30-year analysis period.

Alternative 3 would improve diversity by creating 233 acres of openings, 293 acres of retention clumps, and using heavier thinning. This treatment would increase vertical, horizontal and spatial diversity within the stand.

The diameter distribution chart for Alternative 3 shows fewer trees in the diameter distribution graph than other alternatives, however, the relative percentage of larger trees over 20 inches DBH would be higher under Alternative 3 than the others.

Forest resilience to disturbance factors such as wildfire, forest health issues and adaptability to climate change would be improved.

White fir series

Alternative 3 would again be the most effective in meeting the silvicultural indicators. Planting post treatment would increase the percentage of ponderosa pine to 22 percent. After 30 years, the relative percentage would drop to 16 percent as white fir naturally regenerates. Planted pine would remain a viable component of the stand through the analysis period (pre-commercial thinning may be needed). The SDI levels would be healthy and productive throughout the 30-year period. After 30 years, SDI values would reach 51 percent, still under the threshold for within stand mortality. Forest resilience to disturbance factors such as wildfire, forest health issues and adaptability to climate change would be improved. In comparison, SDI values in Alternative 2 would increase to over 70 percent.

Diversity provided by implementing Alternative 3 would include 435 acres of openings and 585 acres of retention clumps. Heavier thinning would improve spatial diversity and maximize tree growth as compared to the lighter thinning proposed in Alternative 2.

Alternative 3 shows fewer trees in the diameter distribution graph than Alternative 2, however the percentage of larger trees over 20 inches DBH would be higher.

Red fir series

Relatively few stands have stand exam data, making modeling difficult; however, based on the stand exams taken and field walk-throughs, Alternative 2 and 3 would have comparable effects.

Lodgepole series

Alternatives 2 and 3 would result in similar effects. Alternative 3 would be slightly more effective as it includes 1,212 acres of firewood gathering adding additional benefit. Alternative 2 and 3 would both treat 245 acres.

Compliance with law, regulation, policy, and the Forest Plan

All alternatives would be in compliance with law, policy, regulation, and the standards and guidelines for the Klamath National Forest Plan.

Literature Cited

- Agwin, P. 2013. Pacific Southwest Experiment Station, personal Conversation.
- Bareja, G.B. 2011. Plant growth factors in relation to crop production. Edited 26 April 2019 [Online] Available at: <https://www.cropsreview.com/plant-growth-factors.html>
- Fitzgerald, S.A. 2005. Fire ecology of ponderosa pine and the rebuilding of fire-resistant ponderosa pine ecosystems. In: Ritchie, M.W., Maguire, D.A., Youngblood, A. (Technical Coordinators), Proceedings of the Symposium on Ponderosa Pine: Issues, Trends, and Management. USDA Forest Service General Technical Report PSW-GTR-198, pp. 197–225.
- Humple, D.L. and Burnett, R.D. 2010. Nesting ecology of yellow warblers (*Dendroica petechia*) in montane chaparral habitat in the northern Sierra Nevada. Western North American Naturalist 70, 355–363.
- Laacke, R.J. 1990. *Abies magnifica* A. Murr. Pages 71–79 in R. M. Burns, M. Russell, and B. H. Honkala, technical coordinators. Silvics of North America. Volume I. U.S. Department of Agriculture, Agricultural Handbook 654.
- United States Geological Survey. LANDFIRE: Biophysical Setting. U.S. Department of Interior, Geological Survey. [Online]. Department of Interior, USGS. Available: <https://www.landfire.gov/bps.php> [March 2019].
- Larson, J.A. and Churchill, D. 2012. Tree spatial patterns in fire frequent forests of western North America, including mechanisms of pattern formation and implications for designing fuel reduction and restoration treatments. Forest Ecology and Management 267: 74–92.
- Long, J.N. 1985. A practical approach to density management. For. Chron. 61, 23–27.
- Long, J.N. and Shaw, J.D. 2005. A density management diagram for even-aged ponderosa pine stands. West. J. Appl. For. 20, 205–215.
- Lydersen, M.J.; North, M.P.; Knapp, E.E.; and Collins, B.M. 2013. Quantifying spatial patterns of tree groups and gaps in mixed conifer forests: Reference conditions and long-term changes following fire suppression and logging. Forest Ecology and Management 304: 370–382.
- Knapp, E.E.; Skinner, C.N.; North, M.P.; and Estes, B.L. 2013. Long term overstory and understory change following logging and fire exclusion in a Sierra Nevada mixed conifer forest. Forest Ecology and Management 310: 903–914.
- Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research 46(7): 627–638.

- Skinner, C.N., and Taylor, A.H. 2006. Southern Cascades bioregion. Fire in the California ecosystem. Ed. Sugihara, Neil G., Jan W. Van Wagtendonk, Jo Ann Fites- Kaufman, Kevin E. Shaffer, and Andrea E. Thode, Chapter 110, 195-224. Berkley, CA: University of California Press.
- Taylor, A.H. and Skinner, C.N. 2003. Spatial patterns and controls on historical fire regimes and forest structure in the Klamath Mountains. *Ecological Applications* 13(3), pp.704-719.
- Taylor, H.A. 2010. Fire disturbance and forest structure in an old-growth *Pinus ponderosa* forest, southern Cascades, USA. *Journal of Vegetation Science* 21: 561-572.
- Wood, D.L.; Koerber, T.W.; Sharpf, R.F.; and Storer, A.J. 2002. Pests of the native California Conifers. *California History Guides*. University of Press California. Berkeley and Los Angeles, CA. 146-148 and 67-76.
- York, A.R.; Battles, J.J.; and Heald, R.C. 2003. Edge effects in mixed conifer group selection openings: tree height response to resource gradients. *Forest Ecology and management* 179 107-121.

Appendix A – Pathogens

The following is a brief description of pathogens affecting this project area

Root Diseases (*Armillaria mellea*, *Heterobasidion annosum*)- Armillaria root disease is a wood decaying fungus that affects true firs as well as Douglas-fir. Annosum root disease has two host specific forms, P-type affecting ponderosa pine and S-type affecting true firs as well as Douglas fir. Spores from these fungi spread into the root system via cut stumps, mechanical damage or other entry points. Note: applying borax to stumps limits opportunities for entry (personal conversation, 2010 Pete Agwin, Pacific Southwest Experiment Station).

Mistletoe (*Arceuthobium* sp., *Arceuthobium abietinum* sp. *magnificae*)- This plant is an obligate parasite that is host specific to conifers. This plant will attach itself to branches sending roots underneath the bark from which it draws moisture and nutrients. As mistletoe develops it forms large brooms which are valued for wildlife habitat but decreases tree vigor. Each conifer has a specific species of mistletoe which it is susceptible to.

Arceuthobium abietinum sp. *Magnificae* is specific to Shasta red fir. Heavily infected trees suffer significant growth losses and are subject to attack by *Cytospora abietis*, a fungus that kills branches infected by dwarf mistletoe and further reduces growth. Because of reduced vigor, infected trees are more susceptible to bark beetle attack and other diseases

Fir Engraver (*Scolytus ventralis*)- This beetle is host specific to white fir and shasta red fir. It usually attacks the tops of trees eventually killing them or rendering them susceptible to other diseases.

Within the project area this beetle is active at endemic levels. Recent attacks are common reflecting the current high SDI levels and associated inter-tree competition.

Mountain and Western Pine Beetles- (*Dendroctonus ponderosae*, *Dendroctonus brevicomis*) Mountain pine beetle is noted for attacking Ponderosa pine while western pine beetle prefers lodgepole pine, but attacks ponderosa pine as well (Wood et al. 2002).

These insects are active at moderate to high levels attacking lodgepole found within the lodgepole series and ponderosa pine in adjacent areas.

Appendix B – Stand Density Index

Stand density influences the amount of water and nutrients available to individual trees. High stand density, such as what is found in the project area, leads to competition for limited resources needed for growth and survival. Competition, in turn, leads to reduced growth and vigor, increased susceptibility to insects and disease, and to eventual mortality. Stand density affects stand health and the ability of trees to respond to disturbance mechanisms.

Stand density index (SDI) is a relative measure of stocking levels, by species, expressed as a number of 10-inch diameter trees per acre. Reineke (1933) first introduced SDI as a measure of site occupancy. He found that SDI could be consistently applied to calculate a maximum density expected for a given average stand diameter and species. SDI has an advantage over basal area because it is not significantly affected by age and site quality. Maximum SDI values have been developed for a variety of species including ponderosa pine, lodgepole, white fir and Shasta red fir. These values often differ depending on which article is referenced. Using stand conditions and stand exams the following Max SDIs were developed: mixed conifer - 650, lodgepole - 580, white fir - 760, Shasta red fir - 900. A zone of imminent mortality, or where self-thinning begins to occur, is reached at 55 percent of maximum SDI. This would equate to SDI values of 358 for mixed conifer, 418 for white fir, 319 for lodgepole and 495 for Shasta red fir.

In order to minimize self-thinning and associated fuels build-up, and to promote growth, stands should be below 55 percent of maximum SDI (Reineke 1933).

Table B- 1: Detailed explanation of SDI classes.

% Maximum SDI	Competitive Interactions
0 to 24%	Less than full site occupancy, maximum understory forage production.
Low density	No competition between trees, little crown differentiation. Maximum individual tree diameter growth. Minimum whole stand volume growth.
25 to 34%	Less than full site occupancy, intermediate forage production.
Moderate density	Onset of competition among trees, onset of crown differentiation. Intermediate individual tree diameter growth. Intermediate whole stand volume growth.
35 to 55%	Full site occupancy, minimum forage production.
High density	Active competition among trees, active crown differentiation. Declining individual tree diameter growth. Maximum whole stand volume growth. Upper range of zone marks the threshold for the onset of density-related mortality.
Greater than 56%	Full site occupancy, minimum to no forage production.
Extremely high density	Severe competition among trees, active competition-induced mortality. Minimum individual tree diameter and growth, stagnation. Declining whole stand volume growth due to mortality

Appendix C – Assumptions for FVS Modeling

Assumptions that apply to all alternatives:

1. All treatments within each conifer series were averaged together and ran as one treatment for each alternative.
2. All treatments had a species preference for ponderosa pine as leave trees.
3. Regeneration was averaged for all alternatives at 180 trees per acre. This was done to make regeneration constant effects of alternatives could be compared without other biotic factors.
4. Ponderosa pine regeneration was calculated using 220 trees per acre for all acres suitable for regeneration. The number of suitable acres was then averaged across the stand. This resulted in trees per acre of ponderosa pine expected to regenerate across the conifer series by alternative.
5. To estimate the percent of light and heavy thinning the following basal areas were used:
 - Mixed conifer: over 100 square feet of residual basal area was considered light thinning
 - White Fir: over 120 square feet of residual basal area was considered light
 - Red Fir: over 140 square feet of residual basal area was considered light.
6. The No Action values for the diameter distribution graph represent all stands within the project area are only shown as a reference for existing conditions.
7. Diameter distribution charts do not include tree sizes 2 inches diameter at breast height to 5.9 inches to better isolate the effects of treatment and compare with other alternatives. The effects of remaining understories in alternatives will be expressed in the resulting SDI values.
8. The lodgepole conifer series did not have stand exam data collected. Values shown are estimates based on field observations. With little difference between alternatives, lodgepole was not graphed with the diameter distribution chart.

Assumptions for Alternative 2

1. Trees down to 8 inches were removed with the thin from below treatment
2. PCT 0 inches-7.9 inches simulating prescribed burn. Used 70 percent cutting efficiency to allow for 30 percent no treatment retention clumps.

Alternative 3

1. Thinned from below to include all trees, in order to simulate the more intense prescribed burn in Alternative 3 designed to remove all true firs.
2. At 30 years, half of the white fir in the 2-inch class was included as total trees per acre to adjust to FVS growing true fir at a slow rate.
3. Primary and secondary goshawk nest stands were added after modeling was complete. Primary nest stands were added as part of the retention acres in Alternative 3. Reserve nest stands would be thinned to 120 square feet of basal area. This did not significantly affect the outputs of modeling.